

MOUNTAIN-SCALE RADIONUCLIDE TRANSPORT IN THE UNSATURATED ZONE AT YUCCA MOUNTAIN, NEVADA: 3-D STUDIES

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RESEARCH OBJECTIVES

The U.S. Department of Energy is actively investigating the technical feasibility of permanently disposing high-level nuclear waste in an appropriate repository proposed for the unsaturated zone (UZ) at Yucca Mountain, Nevada. The objectives of this study are to evaluate the transport of radioactive solutes and colloids under ambient conditions, from the proposed repository horizon to the water table, and to determine processes and geohydrological features that significantly affect radionuclide transport.

APPROACH

The radionuclide transport model considers the site hydrology and the effects of the spatial distribution of hydraulic and transport properties in the Yucca Mountain subsurface. The migration and retardation of radionuclides are analyzed using EOS9nT (Moridis et al., 1999) and T2R3D (Wu et al., 1996), both of which are members of the TOUGH2 family of codes (Pruess, 1991). These models can describe the complex processes of flow and transport in the Yucca Mountain subsurface, including advection, diffusion, hydrodynamic dispersion, sorption, radioactive decay and tracking of daughters, colloid straining and physical-chemical filtration, and colloid-assisted solute transport. The mountain-scale grid for these 3-D studies of UZ transport consisted of 245,000 elements. A dual-permeability conceptualization was used to describe the fracture-matrix system in the UZ. The radioactive species were released directly into the fractures of the elements corresponding to the proposed repository. We investigated (a) instantaneous release, describing a single catastrophic event, and (b) continuous release, describing a plausible long-term scenario involving the breaching of the waste-containing canisters and the slow discharge of their contents. A total of eleven instantaneously released radionuclides were investigated, in addition to continuously-released radioactive species that included four parents, two chains, and four colloids.

RESULTS

The results of the study indicate that the most important factors affecting radionuclide transport are the subsurface geology and site hydrology—i.e., the presence of faults (they dominate and control transport), fractures (the main migration pathways), and the relative distribution of zeolitic and vitric tuffs. Diffusion from the fractures into, and subsequent sorption onto, the matrix are the main retardation processes. Arrival times at the water table increase with the sorption distribution coefficients of the various species. For certain radionuclides such as ^{239}Pu , the contributions of the decay daughters to the total arrivals at the water table can be very significant. Changes in future climatic conditions can have a significant effect on transport, since increasing infiltration leads to faster transport to the water table. The transport of colloids is strongly influenced by their size

(as it affects diffusion into the matrix, straining at hydrogeologic unit interfaces, and transport velocity).

SIGNIFICANCE OF FINDINGS

Based on these studies, cumulative breakthrough curves for the radionuclides of interest were obtained. Note that because of the extremely conservative approach involved in this study, these curves describe the lower bound of arrival times at the water table.

RELATED PUBLICATIONS

Moridis, G.J., Y.-S. Wu, and K. Pruess, EOS9nT: A TOUGH2 module for the simulation of flow and solute/colloid transport. Berkeley Lab Report LBNL-42351, Berkeley, California, 1999.

Moridis, G.J., Y. Seol, and Y.-S. Wu, Modeling studies of mountain-scale radionuclide transport in the unsaturated zone at Yucca Mountain, Nevada. Berkeley Lab Report LBNL-52567, Berkeley, California, 2003.

Wu, Y.-S., C.F. Ahlers, P. Fraser, A. Simmons, and K. Pruess, Software qualification of selected TOUGH2 modules, Berkeley Lab Report LBNL-39490, Berkeley, California, 1996.

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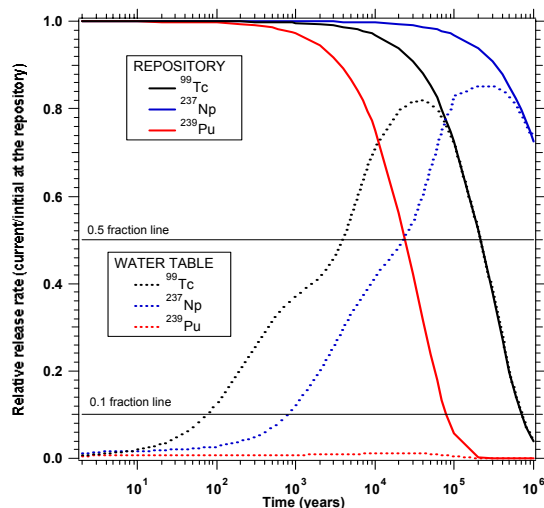


Figure 1. Normalized release rate of ⁹⁹Tc, ²³⁷Np and ²³⁹Pu from the repository horizon (for continuous release and mean present-day infiltration) and their subsequent arrival times at the water table